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Keywords: electronic commerce, information privacy, internet, web surveys

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Jack M. Nilles, Paul Gray, F. Roy Carlson, John Hayes
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Keywords: architectures, e-government, evaluation, interoperability, law, measu

11 Asymmetrical impact of trustworthiness attributes on trust, perceived value framework for cross-cultural study on consumer perception of online auctio
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Lack of trust has been frequently cited to be one of the key factors that discoura e-commerce, while cultural differences affect the formation of trust. As such, thi a conceptual framework to investigate the primary antecedents of online trust a consumer trust into perceived value and purchase intention in online auction. Tv here. First, the authors divid ...

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12 Special issue: Game-playing programs: theory and practice
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In this paper, we introduce the User Interface Pilot, a model-based software too
create the initial specifications for the pages of a website, or for the screens of a
guides the design of these specifications, commonly known as *wireframes*, in a
context of the design within the concepts of *user tasks, user types*, and *data ob*

Keywords: XIML, knowledge-based user interface design, model-based user inte
models, user interface tools, wireframes

14 3.2: IT skills: Staffing and management of e-commerce programs and proje
Fred Niederman
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Electronic commerce (e-commerce) personnel are instrumental in developing ar
programs and projects within firms. In spite of the dot-com bust, the number of
for interactions with customers and suppliers is growing. Personnel competence
decisive force in determining the level of success of e-commerce projects. This
creating a better understanding of b ...

Keywords: IT governance, IT personnel, e-commerce, project management, prc

15 Learning methods to combine linguistic indicators: improving aspectual clas
insights
Eric V. Siegel, Kathleen R. McKeown
December 2000 Computational Linguistics, Volume 26 Issue 4
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Aspectual classification maps verbs to a small set of primitive categories in orde
is necessary for interpreting temporal modifiers and assessing temporal relation
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E-Governance brings urban and rural together and breaks the barrier of distanc Surprisingly, E-Governance have not made enough impact on the people as e-C From the software engineering point of view, E-Governance has a lot of characte e-Commerce and e-Learning. It is enough for e-Commerce and e-Learning to be be proactive. While e-Commerce and e-Learning ...

Keywords: KM cycle, accessibility, e-governance, information management syst of knowledge dynamics, user interface design

18 Special issue: AI in engineering
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20 Computers in education and business: Application of information technolog management of tourist products and destinations, in intermediate regions: i
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This Paper analyzes the opportunity that represents the application of Informati and management of tourist products and destinations in intermediate regions, ir in the main tourist destinations, globalization is bringing an intense company co (OECD) present a fragmentation of small businesses that are becoming less con tourist product isn ...

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Authors

Erik Brynjolfsson Sloan School of Management, Massachusetts Institute of Technology
Lorin M. Hitt Wharton School, University of Pennsylvania
Shinkyu Yang Sloan School of Management, Massachusetts Institute of Technology

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INTANGIBLE ASSETS: HOW THE INTERACTION OF COMPUTERS AND ORGANIZATIONAL STRUCTURE AFFECTS STOCK MARKET VALUATIONS

Erik Brynjolfsson
Sloan School of Management
Massachusetts Institute of Technology
U.S.A.

Lorin M. Hitt
Wharton School
University of Pennsylvania
U.S.A.

Shinkyu Yang
Sloan School of Management
Massachusetts Institute of Technology
U.S.A.

Abstract

An important theme in information systems research is that organizational factors are critical to the success of computer investments. This paper provides broad statistical evidence for this proposition. For our analysis, we have compiled a unique data set of over 1,000 firms which includes the total stock market value of firms, their installed base of computer capital, detailed measures of the organizational structures, and a battery of other factors.

Using a theoretically-grounded model, we find that a one dollar increase in a firm's installed computer capital is associated with an increase in the firm's stock market valuation of over five dollars, while controlling for all other tangible assets. For this to be equilibrium, the financial markets must believe that each dollar of computer capital is accompanied by an average of over four dollars of intangible assets. We then identify a candidate for these intangible assets: certain organizational characteristics, involving the structure of decision-making and the nature of job design, are highly correlated with computer investments. While these organizational characteristics do not appear on a firm's balance sheet, we find that they lead to higher stock market valuations.

Strikingly, firms that combine higher computer investments with these organizational characteristics have *disproportionate* increases in their market valuations. Our findings are quite robust to a variety of alternative models and the results are generally strengthened when we control for potential reverse causality. We conclude that the contribution of computers to a firm's market value is increased when they are combined with certain intangible assets, specifically including the cluster of organizational changes that we have identified.

1. INTRODUCTION

A major theme of recent work on information systems research is that investment in computers and other types of information technology (IT) needs to be coupled with boundary-spanning organizational changes in order to be effective. Similarly, scholars of organizational studies predict that new technologies "will require the development of new organizational forms and systems, such as teams and new incentive systems, which decentralize decision making...and harness the knowledge and intelligence of all members of the organization" (Florida and Kenney 1993). While the traditional, functional division of labor that dominated the industrial economy was efficient in economizing on information processing and communication costs, it can be dysfunctional in an age of cheap information ushered in by computers. In particular, when the costs of information processing and communications change radically, the optimal allocation of decision rights, human capital and incentive systems are likely to change as well (Anand and Mendelson 1997; Wyner and Malone 1997).

Numerous case examples highlight the importance of coupling computer investments with complementary changes in organization. Studies of the implementation of Lotus Notes (Orlikowski 1992) have shown that without organizational structures and incentives to promote information sharing, group collaboration and knowledge sharing features of groupware applications may go largely unused. Similar challenges have been documented in manufacturing environments where new information systems increased the need for cognitive skills in the work force (Zuboff and Bronsema 1984). However, the organizations that are effectively able to make concurrent computer investments and organizational "investments" often reap substantial benefits, although reports of high failure rates of business process redesign projects attest to the difficulty of this change (Sauer and Yetton 1997).

These cases suggest the both the high value and high costs of these types of additional investments. While these costs of organizational change create a barrier to the successful use of computers, the other side of the coin is that once firms have incurred such costs, they have something—a new business process, a new organizational form, a new set of supplier relations —that other firms cannot duplicate easily. In economic terms, they have created new assets.

But is all this painful restructuring worth it? Are their any measurable economic benefits associated with these new "intangible assets"?

We formally test the hypothesis that these intangible assets complement information technology capital just as aluminum wings complement jet engines. Complementary assets are more valuable when used together than when used separately. To realize the potential benefits of computerization, additional "assets," like worker knowledge, new organizational structures, or redesigned incentive systems, may be needed.

If these intangible assets really exist, they should be detectable in at least two ways. First, resulting effect on the firm's market valuation should be measurable, even when the underlying assets cannot be seen or touched. The financial markets, which seek to assess the discounted value of future revenues, provide a valuable telltale for whether these investments are generating value for the owners of the firm. In particular, the market value of a firm which has leveraged computer assets with organizational investments should be *greater* than that of a similar firm which has not incurred these investments. A computer that is combined with complementary intangible assets should be significantly more valuable to a business than a computer in a box on the loading dock.

Second, some of the specific changes that firms make may be directly observable. In particular, numerous authors have suggested that IT is likely to be associated with organizational changes such as greater demand for worker skills and increased levels of employee discretion and decision-making authority (Applegate, Cash and Mills 1988; George and King 1991; Sauer and Yetton 1997). If these practices represent the types of organizational assets we described earlier, then we would expect that the value of IT would be greater in organizations that also adopt these work practices.

Therefore, we can assert the following hypotheses:

Hypothesis 1: *If computer capital is complementary with unmeasured, intangible assets, then firms with higher levels of computerization should have higher stock market valuations, even after controlling for all measured assets on their balance sheets.*

Hypothesis 2: *If computer capital is complementary with certain organizational characteristics (e.g., broader job responsibilities for line workers, more use of self-managing teams), then firms with higher levels of computerization should have higher levels of these variables, even after controlling for other characteristics such as industry, year, size, and other assets.*

Hypothesis 3: *If these organizational characteristics create value, as other assets do, then firms with higher levels of these characteristics should have higher stock market valuations, even after controlling for all measured assets on their balance sheets.*

Hypothesis 4: *If computer capital is complementary with certain organizational characteristics, then firms with* both *higher levels of computerization and higher levels of these characteristics should have* disproportionately *higher stock market valuations, even after controlling for other relevant variables.*

Using data on 1,031 large firms over eight years (1987-1994), we find strong evidence in support of all four hypotheses.

1. Each dollar invested in computers increases firm market valuation of from $5 to $20 (depending on the assumptions of the estimation models), compared with an increase of about $1 per dollar of investment in other assets.

2. Firms that are high IT users are also more likely to adopt work practices that involve a cluster of organizational characteristics, including greater use of teams and broader decision authority.

3. This cluster of organizational characteristics increases a firm's market valuation, and furthermore, these organizational characteristics explain some, but not all, of the unusually large valuation of computers.

4. Firms that use these organizational characteristics have a <u>disproportionately</u> higher market valuation of their computers assets.

Our results are robust to a variety of alternative estimating techniques. Most importantly, they cannot be explained by "reverse causality" running from higher stock market values to greater IT investments. They are consistent with earlier case-based research as well as recent econometric work using production functions. Taken together, these results lend strong quantitative support to the idea that IT is most valuable when coupled with complementary changes in organizational design.

In section 2, we present a sketch of the theoretical model and the data, in section 3 we present our statistical results, and we conclude with a summary and discussion in section 4.

2. ECONOMETRIC MODEL AND DATA

2.1 Derivation of Model for Stock Market Valuations

In this subsection, we sketch the derivation of the stock market valuation model. Additional detail is provided in Appendix A. The basic structure of the model follows the literature on the valuation of capital goods that relates the market value of a firm to the capital goods a firm owns (Brynjolfsson and Yang 1997; Hayashi 1982; Hayashi and Inoue 1991; Wildasin 1984). This literature is often referred to as the "Tobin's q" literature after the pioneering work by James Tobin (1969) in understanding the

relationship between firm value and capital investment.[1] This framework has been empirically adapted and applied to the valuation of R&D by Griliches (1981) and by Hall (1993a, 1993b) and the stock market impact of diversification (Montgomery and Wernerfelt 1988).

We assume that firms face the following dynamic optimization problem in which managers make capital investments (I) in several different asset types and expenditures in variable costs (N) with the goal of maximizing the market value of the firm V. In turn, V is equal to the present value of all future profits. The accumulation of capital investment, less depreciation (δ) produces a vector of capital stock (K, which includes different components of capital K_j). We use the subscript *j* as an index for each of the different capital goods. The capital stock along with variable inputs is used to produce output (F). Unlike traditional production function analyses, we assume that there is some additional cost of making a capital investment which represents an "organizational adjustment cost" ($\Gamma(I,K,t)$). These organizational costs represent the amount of output lost while integrating additional capital into the firm. This yields the following program:

$$(1) \quad \underset{I,N}{Maximize}\ V(0) = \int_0^\infty \pi(t)u(t)dt$$

$$(2) \quad \text{where} \quad \pi(t) = F(K,N,t) - \Gamma(I,K,t)) - N - 1$$

$$(3) \quad \text{given,} \ \frac{dK_j}{dt} = I - \sum_{j=1}^{J} \delta_j K_j, \ \text{for all } j = 1,\ldots,J.$$

One can solve for the market value of the firm that results from this optimization problem (see Appendix A). If there are no organizational adjustment costs needed to make capital assets fully productive [$\Gamma(I,K,t)=0$], then buying a firm is no different from buying a collection of separate assets. Thus, the market value of a firm is simply equal to the current stock of capital assets:

$$(4) \quad V = \sum_{j=1}^{J} K_j$$

However, if there are organizational adjustment costs required to make full use of capital, then the value of an ongoing firm may exceed the value of its separate capital assets. The higher value represents the additional "intangible assets" created when each of the capital assets is integrated into the firm. In this case, the value of the firm is the sum of capital assets, but weighted by the size of the organizational adjustment costs, λ:

$$(5) \quad V = \sum_{j=1}^{J} \lambda_j K_j.$$

For example, if there are two types of capital, computers (c) and other capital (k), then $(\lambda_c - 1)$ would represent the difference in value between computer capital which is fully integrated into the firm vs. computers which are available on the open market, and $(\lambda_k - 1)$ would be the corresponding value for other types of capital. We can then calculate the size of the complementary organizational investments by comparing how much the market values a capital asset that is part of a running firm as compared to the same asset sold separately.

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[1]Tobin's q is a ratio of the market value of a firm (including debt and equity) to the book value of its assets.

2.2 Econometric Issues of Market Valuation

To translate the result of our dynamic optimization model into a specification suitable for empirical testing, we need to specify the different types of capital that we will consider and a set of additional control variables (X) that are likely to influence this relationship. We also sometimes include a firm effect term, α, to capture residual firm differences that are not explained by other control variables. Including an error term, ϵ, we have our estimation equation:

$$(6)\quad V_{it} = \alpha_1 + \sum_{j=1}^{J} \lambda_j K_{j,it} + X_{it}\gamma + \epsilon_{it}$$

Here, i, t, and j are indices of firms, time, and different capital goods, respectively. The coefficients to be estimated are (vectors) α, λ, and γ.

Extending the prior literature on estimates of Tobin's q, we divide assets into three categories: computers, physical assets (property, plant, and equipment), and other balance sheet assets (receivables, inventories, goodwill, cash, and other assets). For the other control variables (X) we will use return on assets, the ratio of R&D capital to assets, and the ratio of advertising expense to assets.[2] This yields our base estimating equation, which we will extend to include organizational investments:

$$(7)\quad V_{it} = \alpha_i + \lambda_c K_{c,it} + \lambda_p K_{p,it} + \lambda_o K_{o,it} + \mathit{controls} + \epsilon_{it}$$

Here K_c, K_p, and K_o represent computer capital, physical capital, and other balance sheet assets, respectively.[3]

There are two issues about this specification that warrant concern. The first problem is that larger firms are likely to have larger residuals that may unduly influence the regression estimates. This can be addressed by using a generalized (or weighted) least squares technique (GLS) to dampen the influence of large residuals. Alternatively, we can use robust regression techniques (least absolute deviation—LAD), which is less sensitive to outliers of all sorts.

A second concern is the potential for reverse causality. While our model seeks to measure whether changes in the value of a firm's capital assets affect its stock market value, it may also be the case that unexpected increases in stock market valuations lead firms to make increased investment in capital assets. To reduce this problem, we apply the standard technique of instrumental variables regression (two stage least squares or 2SLS).[4]

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[2]Return on assets captures short run profit effects that may influence stock market valuation. Advertising and R&D capture other types of nonstandard assets that have been considered in prior work. Finally, we add additional control variables for industry to reduce sample heterogeneity and time to control for general economic trends in stock market valuation. Control variables include return on assets, R&D ratio, advertisement ratio, industry dummies (usally SIC 2-digits), and year dummies.

[3]Our methodology is an example of hedonic regression, which estimates the market's valuation using cross-sectional and time series variations in the market value and the computer capital of the firm. An interesting alternative for measuring the impact of IT on the market value might be an event study methodology. For example Dos Santos, Peffers, and Mauer (1993) and Im, Dow, and Grover (1998) found an interesting positive relationship between IT investment announcements and market value of the firm.

[4]In addition, to control for heterogeneity among firms and to gauge the robustness of our results, we will also perform the estimates using fixed effects and "between" regression, which enables us to separate out effects due to variation over time for the same firm and effects due to variation across firms. These techniques will be discussed further in the results section.

2.3 Data Sources and Construction

The data set used for this analysis is a panel of computer capital and stock market valuation data for 1,000 firms over the 1987 to 1994 time period, matched to a cross sectional survey of organizational practices conducted in 1995 and 1996. A brief description of each data source follows with additional detail in Appendix B.

Computer Technology: The measures of computer use were derived from the Computer Intelligence Infocorp (CII) installation database that details IT spending by site for companies in the Fortune 1000 (approximately 25,000 sites were aggregated to form the measures for the 1,000 companies that represent the total population in any given year). This database is compiled from telephone surveys that detail the ownership of computer equipment and related products. Most sites are updated at least annually with more frequent sampling for larger sites. The year-end state of the database from 1987 to 1994 was used for the computer measures. From this data, we obtain the total capital stock of computers (central processors, personal computers, and peripherals). The IT data do not include all types of information processing or communication equipment and are likely to miss that portion of computer equipment that is purchased by individuals or departments without the knowledge of information systems personnel.[5]

Organizational Practices: The organizational practices data in this analysis uses a series of surveys of large firms. These surveys adapted questions from prior surveys on human resource practices and workplace transformation (Huselid 1995; Ichniowski, Shaw and Prunnushi 1997; Osterman 1994). The questions address the allocation of various types of decision-making authority, the use of self-managing teams, the breadth of job responsibilities, and other miscellaneous characteristics of the workplace (further detail appears in the results section). Organizational data were collected in three waves, covering most of the Fortune 1000. A total of 416 firms provided at least some data for the study. Because some firms on the organizational practices survey do not have complete matching data from CII and Compustat or have missing data on key questions on the survey, most analyses are conducted using a sample size of approximately 380 firms.

Compustat: Compustat data was used to construct stock market valuation metrics and provide additional firm information not covered by other sources. Measures were created for total market value (market value of equity plus debt), property, plant and equipment (PP&E), other assets, R&D assets, and advertising expense.

Overall, the full dataset includes 4,578 observations over eight years for market value and computer capital stock. When we match these data to the organizational practices surveys, we have complete organizational and market value data for 250 firms for a total of 1,705 observations.

3. RESULTS

In this section, we perform regression and correlation analyses to test the four basic hypotheses outlined in the introduction. First, we explore the basic relationship between IT and stock market value for our full sample of firms. We examine the relationship between computer capital and the adoption of specific organizational practices using correlation analyses and construct a single variable, ORG, which captures most of the relevant variation in organization across firms. Third, we investigate the effect of ORG on firm market value. Finally, we study how the combination of ORG and computers affect market value. We also perform a number of robustness checks of our analysis in each section.

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[5]Another potential source of error in this regard is the outsourcing of computer facilities. Fortunately, to the extent that the computers reside on the client site, they will still be properly counted by CII's census.

3.1 Basic Findings for Computers and Market Value

The basic regression analyses (estimates of equation 7) for calculating the effect of computers on market value is shown in Table 1. In the first column, we present basic ordinary least squares results and find that each dollar of property, plant and equipment (PP&E) is valued at about a dollar, and a dollar of other assets is valued at about \$0.70. Strikingly, each dollar of computer capital is associated with over \$15 of market value. This implies that the stock market imputes an average of \$14 of "intangible assets" to a firm for every \$1 of computer capital. All capital stock variables are significantly different from zero, and the high R^2 (~85%) suggests that we can explain much of the variation in market value across firms with our model.[6]

To probe this result further, we investigate how much the correlation between market value and computer investment is driven by variation across firms, e.g., GM vs. Ford (a "between" regression), and variation for the same firm over time, e.g., GM in 1988 vs. GM in 1989 (a "within" or "firm effects" regression). We find that both sources of variation are important but that the effect due to variation between firms is larger. The "between" regression implies a market value of computer capital of nearly \$20. For the within regression, this value is \$5 (but still strongly significant). The within regression can be interpreted as removing <u>all</u> the effects that are unique to a particular firm but constant over time (equivalent to including every possible cross-sectional control variable) so this suggests that factors unique to specific firms are important in determining the market value of computers.[7] Figure 1 and Figure 2 present the relative size of computer coefficients and those of other assets.

Table 1. Effects of Various Assets on Firms' Market Valuation: Baseline Regressions of Different Models

Market Value	Pooled	Fixed Effect Within		Between
	OLS	w/Year	wo/Year	OLS
Computer Capital	15.192*** 1.158	5.076*** 0.891	6.419*** 0.839	19.218*** 2.859
Physical Capital	0.967*** 0.020	1.147*** 0.053	1.251*** 0.053	0.960*** 0.037
Other Assets	0.691*** 0.008	0.830*** 0.012	0.829*** 0.012	0.664*** 0.018
Controls	ROA*** R&D Adv Year*** Industry***	ROA*** R&D Adv Year*** Firm***	ROA*** R&D Adv Firm***	ROA*** R&D Adv Industry***
R Square Observations	0.8758 4578	0.729 4578	0.721 4578	0.887 4578

Key: * - p < .1; ** - p < .05; *** - p < .01

[6]Among control variables, return on assets (ROA) is always significant and large. R&D to asset ratios and advertisement to asset ratios are not always significant. Firm effects, industry effects, and year effects as separate groups are always strongly significant.

[7]In other words, the difference in intangible assets between highly computerized firms and less computerized firms is greater, on average, than the difference within any single firm over time.

Table 2. Effects of Various Assets on Firms' Market Valuation: Balanced Panel Only, Between and Wihtin Regression

	Between Regression			Fixed Effect Within Regression		
	OLS	GLS	LAD	GLS	LAD	2SLS
Computer Capital	22.285*** 4.193	18.540*** 1.454	14.824*** 3.545	5.584*** 0.921	4.308*** 1.154	9.945*** 2.239
Physical Capital	0.968*** 0.049	1.014*** 0.016	0.984*** 0.019	1.244*** 0.055	1.169*** 0.113	1.069*** 0.057
Other Assets	0.654*** 0.024	0.656*** 0.010	0.652*** 0.088	0.811*** 0.015	0.814*** 0.086	0.820*** 0.015
Controls	ROA*** R&D Adv* Industry***	ROA*** R&D*** Adv*** Industry***	ROA*** R&D*** Adv*** Industry***	ROA*** R&D Adv Year*** Firm***	ROA*** R&D Adv*** Year*** Firm***	ROA*** R&D Adv Year*** Firm***
R square Observations	0.892 3312	0.069 3312	0.674 3312	0.681 3312	0.836 3312	0.670 3212

Key: * - p < .1; ** - p < .05; *** - p < .01

In Table 2, we examine how robust this result is to variations in econometric methods. For this analysis, we restrict the sample to a balanced panel[8] to get maximum data consistency and apply different regression techniques: generalized least squares (GLS) and least absolute deviation (LAD) regression[9] to control for heteroskedasticity, and two stage least squares (2SLS) to control for reverse causality. Overall, the basic results are consistent whether we use balanced or unbalanced panels and whether we correct for heteroskedasticity using GLS or LAD in both between and within regressions.[10]

The last column of Table 2 addresses the possible bias due to reverse causality. If investments in computer capital are very responsive to changes in market valuation, then the coefficient estimate of computer capital may be biased upward. The standard method of eliminating bias due to reverse causality is to identify variables that predict IT investment for fundamental, long-term reasons but are not affected by short term market fluctuations. Normally this is very difficult, but in this context we have access to computer prices, which are strong drivers of IT investment, but largely determined by fundamental technological progress in the semiconductor industry and not transitory stock market fluctuations.

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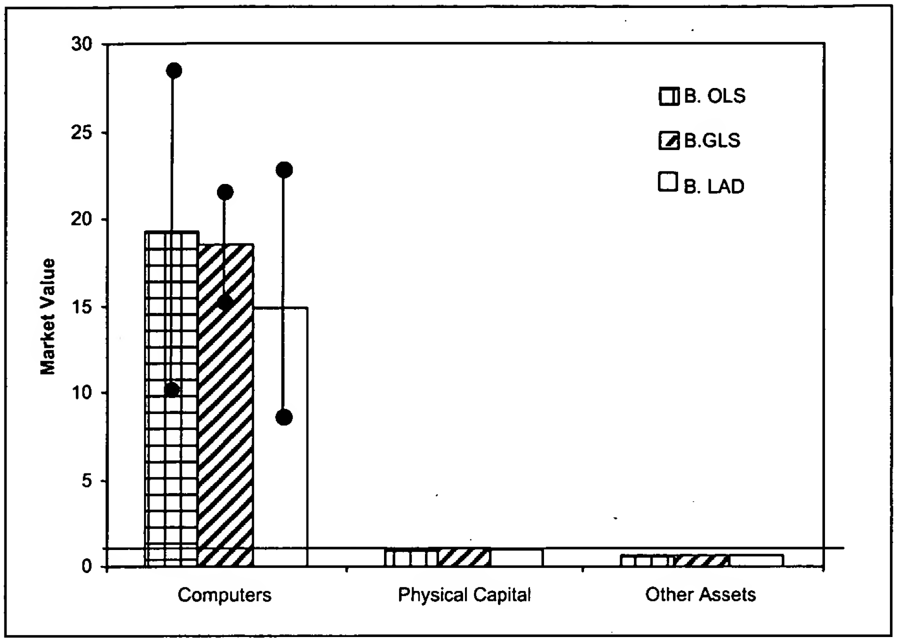
[8]In other words, we exclude all firms which are missing any data in any year.

[9]LAD regression minimizes the absolute value of the deviation of the actual and fitted values, as opposed to the square of the difference as is done for OLS. Standard errors for the LAD estimates are done using bootstrapping techniques with 100 repetitions to obtain the empirical distribution of the coefficient estimates.

[10]While a plot of regression residuals (not shown) suggests strong size-based heteroskedasticity, the results are changed very little with alternative estimation methods.



• 95% confidence interval is drawn for computer coefficients.
• Other coefficients' two standard errors range from 0.02 to 0.16, too small.

Figure 1. Relative Size of Market Valuation: Between Estimates

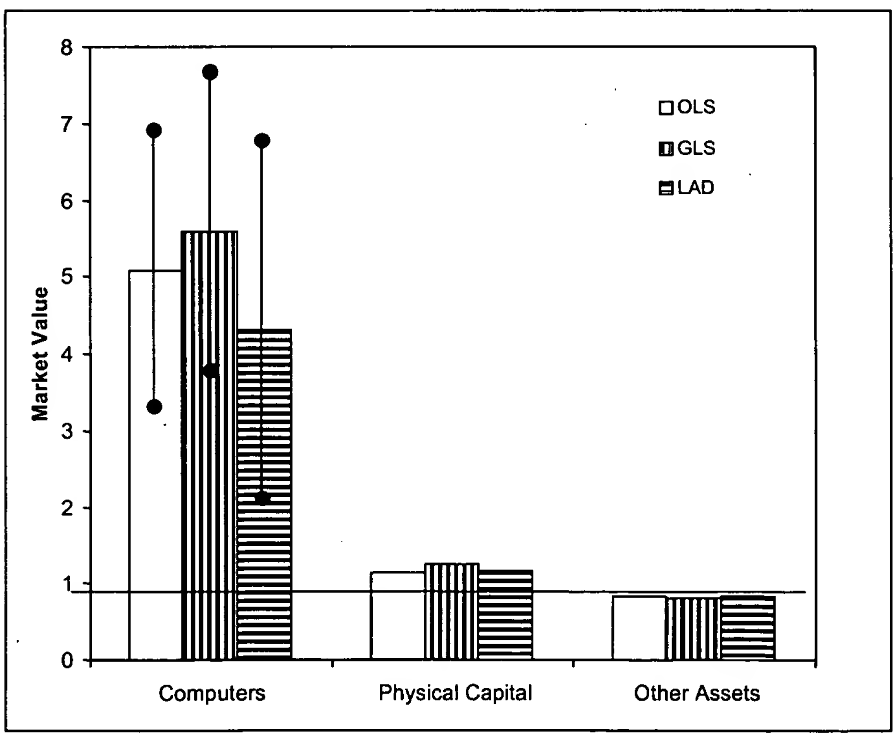


Figure 2. Relative Size of Market Valuation: Firm Effect Within Estimates

We first model the investment in computers as a function of price and other exogenous variables in our model to obtain a predicted value of IT free from any reverse effects due to market.[11] We then use this measure of computer capital.

In this regression, the coefficient on computers is nearly doubled to $10. Thus, we find no evidence that the computer coefficient is biased upward by endogeneity. Although most of the other coefficients are similar, a Hausman test rejects the ordinary least squares (OLS) specification in favor of 2SLS. Therefore, if anything, the estimates in Table 1 and the rest of Table 2 appear to be conservative.

These regressions provide strong support for hypothesis H1—computers are associated with a substantial amount of intangible assets. Our estimates imply that these intangible assets dwarf the directly measured value of computer hardware that shows up on the balance sheet. In addition, the results on control variables and other factors give us confidence that our regression model is consistent with prior expectations: most other assets are worth approximately a dollar. In addition, the results corroborate an earlier exploratory analyses found by Yang (1994) using a different, smaller set of IT data from International Data Group. Furthermore, the basic results do not appear to be upward biased by reverse causality. Finally, the large difference between the "*between*" and "*within*" regressions suggests substantial effects of firm-specific characteristics on the value of computer capital. We will explore direct measures of one component of these organizational characteristics in the next section.

3.2 Basic Findings Regarding Role of Organizational Structure

In this section, we examine the correlation between computers and internal organization. All correlations use Spearman rank order correlations[12] between various measures of computers and the organizational variables, controlling for firm size (employment), production worker occupation, and industry.[13] Three different measures of IT are used, including the total value of IT installed base (ITCAP), total central processing power[14] in millions of instructions per second (MIPS), and number of personal computers (TOTPC). Multiple measures are employed because they capture slightly different aspects of computerization (for example, MIPS measures centralized computing, while TOTPC measures decentralized computing).

In Table 3, we present correlations between multiple measures of IT and four dimensions of organizational design: use of teams and related incentives, individual decision authority, investments in skills and education, and team-based incentives. Consistent with Hypothesis 2, we find that across multiple measures of IT and multiple measures of organization, firms that utilize more IT tend to use more teams, have broader job responsibilities, and allocate greater authority to their workers, even after controlling for firm size and industry.

In addition to being correlated with IT, these practices are all correlated with each other. Following Hitt and Brynjolfsson (1997) we construct a composite variable (ORG) as the standardized (mean 0, variance 1) sum of the individual work practice variables. This allows us to capture an organization's overall tendency to use this collection of work practices in a single construct which can be used for further analysis. A principal components analysis, Table 4, shows that all components of this variable load highly on a single factor (which explains approximately 35% of the variance of these measures), and a scree plot (not shown) suggests

[11]Our assumption that computer prices are driven by supply shifts and not demand is born out by a negative correlation between computer price and quantity sold. To capture the possibility that the responsiveness of computer investment to price (price elasticity) varies across industry, we allow the price term to vary by industry (at the 2-digit SIC level).

[12]Results are similar when probit or ordered probit regression is used. We report Spearman rank order correlations because they are easier to interpret given the non-metric nature of most of our work system variables.

[13]Included are separate controls for mining/construction, high technology manufacturing (instruments, transportation, electronics, computers), process manufacturing (paper, chemicals, petroleum), other non-durable manufacturing, other durable manufacturing, transport, utilities, trade, finance, and services.

[14]Total central processing power does not include the processing power of personal computers.

that this is the only non-noise factor. The composite variable, ORG, is highly correlated with computerization. Thus, we have additional strong support for our second hypothesis. In the remaining section of the results, we will explore the influence that this cluster of practices has on the market value of the firm as well as the market value of computer capital.

Table 3: Correlations Between IT Measures and Organizational Structure

Measure (scale in parenthesis)	IT Capital	MIPS	TOTPC
Structural Decentralization			
Self-Managing Teams (1-5)	.17***	.22***	.20***
Employee Inv. Grps (1-5)	.07	.08	.08
Broad Jobs (1-5)	.07	.12*	.10*
Individual Decentralization			
Pace of Work (1-3)	.04	.06	.02
Method of Work (1-3)	.16***	.20***	.15***
Composite: 7 Measures^	.12*	.14**	.16***
Individual Control^	.11*	.15**	.15**
Team Incentives			
Team Building	.15***	.19***	.18***
Promote for Teamwork	.02	.10*	.88
Skill Acquisition			
Training (% staff)	.14**	.15***	.14**
Screen for Education (1-5)	.16***	.18***	.21***
ORG Composite	**.24*** **	**.30*** **	**.25*** **

Spearman partial rank order correlations controlling for industry, employment, and production worker occupation. N = 300-372, depending on data availability.

Key: * - p < .1; ** - p < .05; *** - p < .01
^ - Limited to second and third waves of survey (N = 276)

Table 4. Unrotated Principal Components for ORG Variable Construction

Work Practices	Loading First Principal Component	Loading Second Principal Component
Self Managing Teams	0.751	0.008
Employee Involvement Groups	0.707	0.176
Decentralized Pace Decision	0.528	-0.628
Decentralized Method Decision	0.572	-0.456
Team Building	0.747	0.250
Promote for Teamwork	0.401	0.367
Screen for Education	0.466	-0.095
Training (% Staff Involved)	0.425	0.408
Percent of Variance Explained	24.8%	12.6%

3.3 Findings Regarding Effect of Organizational Structure on Market Value

3.3.1 Organization Variable in Market Value Equation

To this base equation, we also consider the effects of adding terms representing organizational characteristics such as human capital and decentralized work systems. We then investigate the direct relationship of these measures on market value as well as their effect on the market value of computers through interaction terms. This yields the following estimating equation:

$$(8)\quad V_{it} = \alpha_i + \lambda_c K_{c,it} + \lambda_p K_{p,it} + \lambda_o K_{o,it} + \omega_1 ORG_i + \omega_2 ORG \cdot K_{c,it} + controls + \epsilon_{it}$$

A test of our third hypothesis (i.e., that organizational investments can be treated as intangible assets) is whether the ORG has a positive contribution to market value. Furthermore, if the estimated market value of IT drops when we include ORG in the equation, it suggests that part of the high market valuation of IT in the previous regressions that were based on equation 7 was due to a correlation with a previously unidentified and unmeasured organizational assets.

A test of our fourth hypothesis (i.e., a positive synergy between IT and organizational investments) is to examine whether IT is more valuable in high ORG firms; that is, testing the null hypothesis, $\omega_2 = 0$ against $\omega_2 \neq 0$.

We examine several market value equations that also include the ORG variable as a measure of organizational capital in Tables 5, 6, and 7. The first three columns in Table 5 report the same analysis of market valuation of computers with matched sub-sample. The coefficients broadly coincide with the results from the larger sample shown in Tables 1 and 2.

Table 5. Effect of IT and ORG on Market Value

	Matched Sample Baseline Estimates			Adding ORG Variable Alone	
	Pooled	Within	Between	Between	Pooled
Computer	10.901*** 1.578	7.946*** 1.297	13.845*** 4.213	8.487* 4.484	6.708*** 1.588
ORG				506.0* 271.2	529.5*** 122.1
Physical Capital	0.921*** 0.034	1.540*** 0.084	0.878*** 0.078	0.749*** 0.093	0.83138*** 0.0385
Other Assets	0.867*** 0.027	0.770*** 0.045	0.864*** 0.064	0.902*** 0.065	0.88359*** 0.02631
Controls	ROA*** R&D*** Adv Year*** Industry***	ROA*** R&D Adv Yar*** Firm***	ROA*** R&D** Adv NA Industry***	ROA*** R&D** Adv NA Industry***	ROA*** R&D*** Adv Year*** Industry***
R Square Observations	0.805 1705	0.741 1705	0.802 1705	0.805 1705	0.827 1705

When we simply add the ORG variable to the baseline market value equation, we find that it has a large and statistically significant contribution as shown in Table 5 columns 4 and 5. Firms that are one standard deviation above the mean in ORG, have a market value that is about $500 million higher, *ceteris paribus*. Evaluated at the mean, one standard deviation of ORG variable corresponds to the 8% increase in market value. The point estimate of computer capital coefficient drops about 40%. This suggests that ORG is a substantial component of the previously unidentified "firm effect" that influences the value of IT. The contribution of most of the other types of capital assets drops slightly, but not significantly.[15]

3.3.2 Interaction Between Organization and Computers

Table 6 presents the results when both ORG and its interaction with computer capital are included in the regression. The magnitude of the interaction term between IT and ORG is about 7 in pooled estimation. This strongly supports hypothesis 4. In fact, it suggests that each dollar of computer capital is associated with an increase in market value of an *additional* seven dollars in firms that are one standard deviation above average in ORG.[16]

[15]Results from between regression and pooled regression are essentially similar (within is omitted since it is not meaningful to estimate the coefficient of a time-invariant variable).

[16]In between regression, the coefficient of interaction term increases to ten, but the differences are not statistically significant. Pooled regression and between regression yield similar results for other coefficients.

Table 6. Effect of Interaction on Market Value

Market Value	Pooled	Pooled w/other Interactions	Between	Between w/other Interactions
Computer	3.112 2.082	3.077 2.181	7.151 4.652	6.747 4.777
ORG	251.** 123.9	230.2* 134.6	104.0 267.4	155.0 286.3
ORG x Computer	6.909*** 1.275	6.982*** 1.465	9.433*** 3.136	10.375*** 3.771
ORG x Physical Capital		0.019 0.032		-0.030 0.076
ORG x Other Assets		-0.010 0.021		-0.005 0.050
Physical Capital	0.928*** 0.034	0.913*** 0.042	0.880*** 0.078	0.902*** 0.096
Other Assets	0.815*** 0.028	0.823*** 0.036	0.775*** 0.069	0.784*** 0.086
Controls	ROA*** R&D*** Adv Year*** Industry***	ROA*** R&D*** Adv Year*** Industry***	ROA*** R&D*** Adv NA Industry***	ROA*** R&D*** Adv NA Industry***
R Square Observations	0.810 1705	0.810 1705	0.862 1705	0.862 1705

One possible explanation of these results is that ORG makes all types of capital more valuable and since capital investments tend to be correlated with each other, we are erroneously attributing this all to computers. When we include additional interaction terms between ORG and Other Capital (columns 2 and 4 of Table 6), we find that this relationship is *unique* to computers: the coefficients on the added interaction terms are not significant and there is little change in other coefficients. This indicates that ORG is an intangible asset that is particularly strongly associated with IT.

As the organization variable, ORG, is measured once per firm, we cannot apply fixed-effect model to estimate its coefficient. However, since computers do vary over time, their interaction with ORG is time varying as well, which enables firm effects estimation. The results (shown in Table 7) suggest that evidence of an interaction between ORG and IT is evident even in the firm effects analysis. The coefficient is reduced although still borderline significant ($p < .07$), but when the direct computer effect is also removed (which is highly collinear with the interaction term in this model), the coefficient rises to 4.4 and is strongly significant and the R^2 is little changed. Thus, we can conclude that the market value of computerizing is substantially higher in high ORG firms.

Table 7. Effect of Interaction: Firm Effect and Instrumental Variable Estimation

Market Value	Firm Effects	Firm Effects w/o Computer Direct	Pooled 2SLS
Computer	4.425*** 1.967		7.221 7.382
ORG			-135.3 168.2
ORG x Computer	2.202* 1.240	4.233*** 0.851	17.897*** 4.611
Physical Capital	1.467*** 0.088	1.476*** 0.088	0.991*** 0.066
Other Assets	0.718*** 0.047	0.722*** 0.047	0.598*** 0.047
Controls	ROA*** R&D Adv*** Year*** Firm	ROA*** R&D Adv*** Year*** Firm	ROA*** R&D Adv*** Year*** Firm
R Square Observations	0.743 1705	0.743 1705	0.790 1705

The final column of Table 7c shows the instrumental variable estimate.[17] In this regression, the interaction becomes stronger in magnitude and significance level suggesting that reverse causality is not leading to overestimates of the effect of computers or their interaction with ORG.

3.3.4 *Non-parametric Estimation*

The above results suggest that in high ORG firms each dollar of computer capital is associated with more intangible assets than it is in centralized, low-skill firms. If the stock market is valuing these firms properly, then this suggests that the benefits of computerization are likely to disproportionately go to firms that are highly decentralized.

Figures 3 and 4 graphically capture this idea by plotting results from non-parametric regressions. Figure 3 is a level plot of fitted values of market value regression on both computer capital and ORG variables, after netting out effects of other variables. Figure 4 is a contour plot from the same regression. We can see a clear picture of the interaction effect between computers and the ORG variable, which captures most of decentralized work practices. Firms that are high in IT and also high in ORG have much higher market values than firms that have one without the other.

[17]Treating ORG as exogenous, but including additional computer price x ORG instruments.

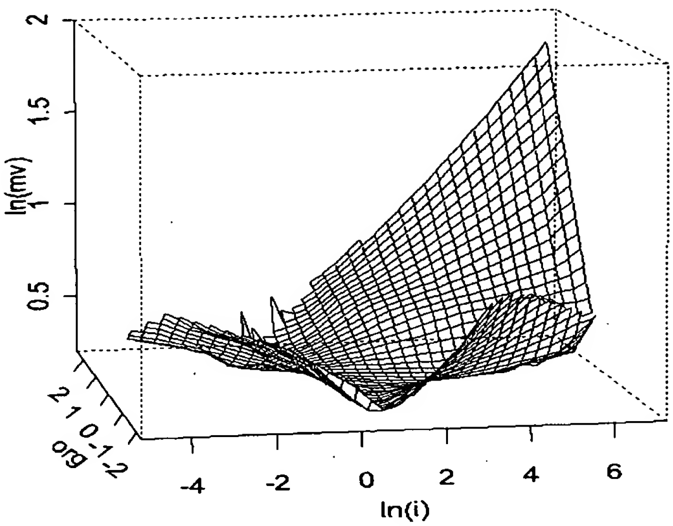


Figure 4. Market Value 3-D Plot by Organization and IT
Non-parametrically Estimated Values via a Local Regression Model

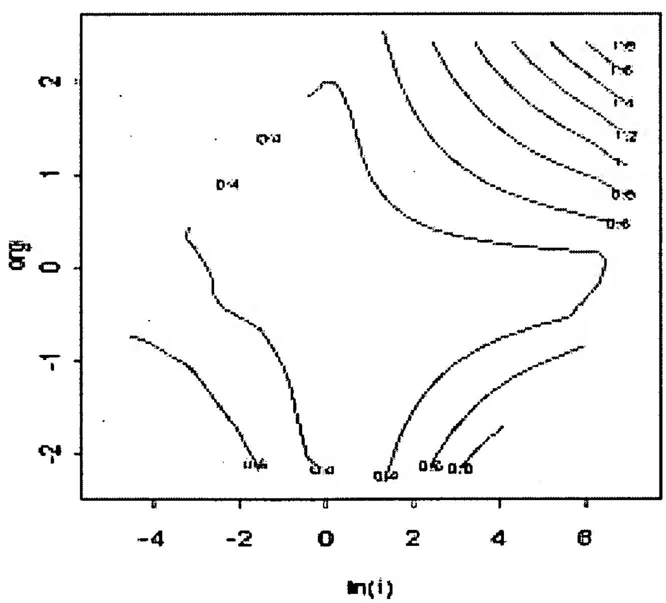


Figure 4. Market Value Contour Plot by Organization and IT
Estimated Fitted Values via a Local Regression Model

4. DISCUSSION AND CONCLUSIONS

The organizational adjustment costs that firms lament when installing computer capital, including costly investments in training, wrenching organizational change, and conscientious relationship-building are not simply wasted. Instead, on average, they create intangible assets that increase revenues but are difficult for competitors to duplicate. Therefore, our results demonstrate that the costs of creating intangible assets should not necessarily be viewed as expenses to be written-off, but rather can be viewed as investments that create an ongoing revenue stream.

Our main results are consistent with each of the four hypotheses described in the introduction:

- The financial markets put a very high value on installed computer capital, substantially exceeding the valuation placed on other types of capital.
- Computer-intensive firms have distinctly different organizational characteristics, involving teams, broader jobs, and greater decentralization of decision-making.
- Firms with these organizational characteristics have higher market valuations than their competitors, even when all their other measures assets are the same.
- Firms with *both* higher levels of computer investment and these organizational characteristics have a *disproportionately* higher market valuations than firms that are high on only one or the other dimension.

These striking findings are quite robust to different data sources, numerous different estimating equations, and corrections for reverse causality. Taken together, these results provide strong evidence that the combination of computers and organizational structures creates more value than the simple sum of these contributions separately.

Our interpretation has focused on the assumption that the stock market is approximately correct in the way it values information technology and other capital investments. The fact that our results apply to a broad segment of the economy over nearly a full business cycle suggesting that fads, industry idiosyncrasies, and investor errors are not driving the results. In

fact, year-by-by estimation shown in Table 8 indicates a consistently high valuation of computer capital throughout our period.[18] Interestingly, productivity analysis by Brynjolfsson and Hitt (1997) shows that the long run productivity benefits are approximately five times their capital cost, consistent with a valuation of IT five times higher than the valuation of ordinary capital.

By analyzing several hundred firms over a period of eight years, our research helps to document, analyze, and explain the extent to which computerization is associated with both direct and indirect measures of intangible assets. Furthermore, our methodology enables use to understand the pattern of interactions among IT, organizational practices and market valuations, and thereby detect complementarities. If these assets are in fact becoming more important in modern economies, in part because of the information revolution engendered by computers and communications, then it is incumbent upon us to understand not only particular cases, but also any broader relationships and patterns that exist in the data.

In summary, our model and evidence support the hypothesis that installing computers is typically associated with the creation of valuable, if previously unmeasured, organizational assets. These organizational assets are evident both directly, in the different work systems use by high IT firms, and indirectly, in the way that the financial market values computer-intensive firms proportionally higher. The performance regressions suggest that the reason that IT is associated with these organizational assets is *not* simply coincidence, but rather that they create more value when used together than when used separately.

Table 8. Year-by-Year Fluctuation of Market Valuation

Years	1987-88	1989-90	1991-92	1993-94
Computer Capital	28.435*** 3.962	15.966*** 3.483	21.082*** 3.647	11.965*** 1.665
Physical Capital	0.821*** 0.027	0.994*** 0.034	1.024*** 0.048	0.989*** 0.042
Other Assets	0.655*** 0.015	0.672*** 0.015	0.661*** 0.022	0.719*** 0.015
Contro.s	ROA*** R&D*** Adv Year Industry***	ROA*** R&D** Adv** Year Industry***	ROA*** R&D Adv Year Industry***	ROA*** R&D Adv Year** Industry***
R Square Observations	0.907 1090	0.909 1089	0.840 1182	0.887 1217

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[18]We can reject the null hypothesis that the market valuation of computers is less than eight in any one period. We can also strongly reject the hypothesis that computer capital's coefficient is equal to those of other types of capital.

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Appendix A
Mathematical Notes

Derivation of the Estimating Equations

This mathematical note is a simpler variation of the appendix in Brynjolfsson and Yang (1997), which is in turn based on Wildasin (1984). It extends the earlier work by providing some auxiliary derivations needed for the discussion of this paper.

We may assume that firms face the following dynamic optimization problem.

(1) $$\underset{I}{Maximize}\ V(0) = \int_0^\infty \pi(t)u(t)dt$$

(2) $$\text{where } \pi(t) = (F(K,N,t) - \Gamma(I,K,t)) - N - I$$

(3) $$\text{given } \frac{dK}{dt} = I - \sum_{j=1}^{J} \delta_j K_j$$

Here a firm maximizes its objective function, market value $V(0)$ at time t = 0, which is equal to the discounted profit stream $\pi(t)$ by the discount factor $u(t)$. The decision variable is the investment vector I, and the constraint is the depreciation rule given in the equation (3). $F(K,N,t))$ is the amount of output the firm can produce using capital input vector equal to K and variable input vector equal to N. In addition, we posit that there is some adjustment costs taking the form of lost output $\Gamma(I,K,t)$. δ_j is the depreciation rate of the capital good K_j. All the variables except for time t and depreciation rate δ are in dollar value.

Then the hamiltonian of the optimization problem can be given:

(4) $$H(I,K,Nt) = ((F(K,N,t) - \Gamma(I,K,t)) - N - I)u(t) + \lambda(I - \sum_{j=1}^{J} \delta_j K_j)$$

Here the Lagrangian multiplier vector λ represents the shadow value vector of one unit of each capital good; i.e., λ_j is the shadow value of capital good K_j. If the valuation of financial markets is correct, λ_j is the value of one additional unit of capital good K_j.

We assume the following to make the analysis simple.

(A1) $F(K,N)$ and $\Gamma(I,K)$ are linear homogenous functions over (K,N) and (I, K) respectively. This assumption is equivalent to constant to return to scale.

(A2) $\Gamma(I,K)$ are twice continuously differentiable in I and K. $\Gamma(0,K) = 0$, and $\Gamma(I,K) \geq 0$; $\Gamma_I > 0$, and $\partial^2\Gamma/\partial I \partial I'$ are positive definite.

A1 is nothing but the constant return to scale assumption and A2 captures the shape of adjustment cost function. It is increasing in investment and convex in investment.

The first order conditions of the hamiltonian under these assumptions can be given:

(F1) $F_N - l = 0$, where F_N is the partial derivative of F with respect to the vector N, and l is the vector of ones.

(F2) $\lambda_j - (\Gamma_j + 1)u = 0$ for all j and t.

(F3) $\dot{\lambda} = -(F_{k_j} - \Gamma_{k_j})u + \lambda_j \delta_i$ for all j and t

And the transversality condition is:

(F4) $\lim_{t\to\infty} \lambda(t)K(t) = \lambda(\infty)K(\infty) = 0$

Let us consider economic interpretations of these conditions. F1 is the familiar marginal productivity condition: the dollar values of marginal product of inputs equal to its dollar value of the input. F2, $(l + \Gamma_I)u = \lambda$, means that total cost of unit of investment is the shadow value of that capital. Now from the transversality condition, we can write

Now from the transversality condition, we can write

(5) $\lambda_j(0)K_j(0) = \lambda_j(0)K_j(0) - \lambda_j(\infty)J_j(\infty) = -\int_0^\infty(\dot{\lambda}_j K_j + \lambda_j \dot{K}_j)dt$

Using the three first order conditions of the maximization problem, observe the following:

(6)
$$-(\dot{\lambda}_j K_j + \lambda_j \dot{K}_j)$$
$$= [(F_{K_j}K_j - \Gamma_{K_j}K_j - \Gamma_{I_j}I_j) + \sum_k (F_{N_k}N_k - N_k)]u$$

By the Euler's theorem for the first degree homogeneous funcion G in vector X.

$$\nabla G(X)^T X = \sum G_{X_i}X_i = G(X).$$

Applying this theorem, since π is homogenous of degree one in in K, I, and N, we can obtain:

(7) $\sum_{j=1}^{J} \lambda_j(0)K_j(0) = \int_0^\infty ((F - \Gamma) - N - I)u(t)dt = \int_0^\infty \pi(t)u(t)dt = V(0)$

High Market Value of IT Due to High Adjustment Costs

It is very easy to see if installment is costly, the installed capital worth more. Let us see this more formally.

By the homogeneity of degree one of the functions of $\Gamma(.)$, we can define:

$$\gamma(I/K) \equiv \Gamma(I,K)/K = \Gamma(I/K,1);$$

Then $\Gamma_I(I,K) = \partial\Gamma/\partial I = K\,\partial[\Gamma(K,I)/K]/\partial I = K\,\partial\gamma(I/K)/\partial I = K\,\gamma'(I/K)\,1/K = \gamma'(I/K)$. By the assumptions of the adjustment functions we know or can easily derive the following:

(8) $\gamma'(I/K) > 0 < \gamma'(I/K)$

Now from one of the first order conditions, F2, we know the market value of one unit of capital goods is:

(9) $\gamma = (\Gamma_I + 1) = (\gamma + 1)$

Let u = I/K, then

(10) $\partial\lambda/\partial u = \gamma'' > 0$, by equation (8).

We just proved that the market value of one unit of capital good is higher when the investment rate is higher, *ceteris paribus.*

There may be another source of higher adjustment costs of IT investment. As IT is a new technology still being developed rapidly, IT investments may accompany considerable changes in the structure and behavior of organizations. In our model, this idea can be captured as $\gamma_c > \gamma_o$, computer capital's adjustment cost function is monotonically larger than those of other types of capital. If that is the case, by monotonic convexity of γ, respectively; $\gamma'_c > \gamma'_o$. According to equation (9), we can immediately see $\lambda_c > \lambda_o$.

Excess Marginal Product of IT Capital

The excess marginal product of computer capital also can be explained in the same framework. The output function can be restated as follows when adjustment costs take the form of foregone output. Let us assume that the adjustment cost function is $G(I,K,t) = \Sigma_j \Gamma^j(I_j, K_j, t)$, additively separable. Then the production function can be restated:

(11) $Y(K,L,I,t) = (F(K,L,t) - \Sigma_j \Gamma^j(I_j, K_j, t))$

Now we assume $\partial F/\partial K_j = \partial F/\partial K_j$ for all i and j. This assumption is for convenience only. In a no adjustment cost economy, there should be no excess returns on any specific capital. Otherwise, firms would invest more on that capital to exploit away the excess returns. We also assume $\Gamma^j = \Gamma^i$ for all i and j. The second assumption is temporary and harmless, and will consider the relaxation of this assumption. Then we can say that the first derivatives of all Γ's with respect to K_j equal to γ as in the above subsection. Under this formulation, the marginal product of each capital good is:

(12) $Y_{Ki} = (F_{Ki} - \Gamma^i_{Ki} = (F_{Ki} + \gamma'(I_i/K_i)/K_i^2)$

The installed capital goods in the adjustment cost economy contribute to output in two ways: first, directly increasing output, $\partial F/\partial K$; and secondly reducing adjustment costs of new investments, $\gamma'(I/K)/K^2$. The computer capital's excess return can be viewed this way.

If one capital good's investment rate I/K is higher than that of others, then the marginal product of that capital should be higher as is monotonously increasing, *ceteris paribus*. Also if the level of one capital good is smaller than that of other's, the marginal product is also higher. These two conditions are exactly the case of computer capital. Thus the second term of the above equation is unambiguously larger for computer capital than for non-IT capital. The model suggests that even when computer capital is nothing special except for the rapid price decline, we should observe excess returns. If computer capital's adjustment cost function is also monotonously larger than that of other capital's as discussed in the above subsection, the excess returns should go up more. If it is costly to install computer capital, the installed capital should earn more.

This way of looking at the problem is so obvious that it is quite surprising hardly any researcher has yet formalized this idea. There is another interesting merit of the above formulation. Given the computer capital's excess returns identified by some researchers, we can actually estimate the adjustment cost parameters from equation (12).

Appendix B
Data Description

The variables used for this analysis were constructed as follow:

IT Capital. We take total purchase value of computer equipment as reported by Computer Intelligence Corp. and deflate it using an extrapolation of Gordon's (1990) deflator for computers (price change -19.3% per year).

Physical Capital. The source of this variable is Standard &Poor's Compustat Annual Dataset. We consider two options to construct the variable. The first is to construct the variable from gross book value of physical capital stock, following the method in Hall (1990). Gross book value of capital stock [Compustat Item #7 - Property, Plant and Equipment (Total - Gross)] is deflated by the GDP implicit price deflator for fixed investment. The deflator can be applied at the calculated average age of the capital stock, based on the three year average of the ratio of total accumulated depreciation [calculated from Compustat item #8 - Property, Plant & Equipment (Total - Net)] to current depreciation [Compustat item #14 - Depreciation and Amortization]. Another method is just to use the net physical stock depreciation [calculated from Compustat item #8 - Property, Plant & Equipment (Total - Net)]. In productivity literature the first method should be used, but in market value estimation we adopt the second approach for the consistency with market value and other assets, which is measured in current dollars. The dollar value of IT capital (as calculated above) was subtracted from this result.

Other Assets. The other assets variable is constructed by the total asset [Compustat Annual Data item #6] minus physical capital constructed above. This item includes receivables, inventories, cash, and other accounting assets such as goodwill reported by companies.

Return on Assets (ROA). Compustat PC plus mnemonic code ROAA, which is a two year moving average of return on assets.

R&D Asset Ratio. Constructed from R&D expenses [Compustat annual item #46]. Interestingly, this item includes software expenses and armortization of software investment. R&D stock is constructed using the same rule in Hall (1993a, 1993b). She applied a 15% depreciation rate, so we did. The final ratio is just the quotient of the constructed R&D stock and total assets. Less than half of the firms in our sample report R&D expenses. The missing values are filled in using the average of the same industry (SIC 4-digits).

Advertising Asset Ratio. Constructed from advertising expenses [Compustat annual item #45]. Less than 20% of our sample of firms report the item. The same rule with R&D assets ratio is applied.

Market Value. Fiscal year end s common stock value plus preferred stock value plus total debt. In Compustat mnemonic code, it is MKVALF + PSTK+DT, which represents total worth of a firm assessed by financial market.

Organization Variable (ORG). The variable is constructed from survey items conducted by us in 1995 and 1996. The construction procedure using principal component analysis is described in the text. This variable captures the degree of new organizational practices identified by Osterman (1994), MacDuffie (1995), and Huselid (1995).

Computer Price. The source of the price of computers is the National Income Product Account (NIPA) by National U.S. Bureau of Economic Analysis (BEA). This is quality adjusted price index described in Triplett (1989).

Systems analysis and modeling: A learning experience based on commodity future

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INDEX TERMS

Primary Classification:

I. Computing Methodologies
- I.6 SIMULATION AND MODELING
  - I.6.4 Model Validation and Analysis

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SYSTEMS ANALYSIS AND MODELING: A LEARNING EXPERIENCE BASED ON COMMODITY FUTURES TRADING

Robert D. Landel[1] and Charles C. Chewning, Jr.[2]

[1]University of Virginia

[2]C. H. Bailey Group, Cardiff, Wales

ABSTRACT

The speculative environment of the commodities futures market offers a setting in which an experiment in systems analysis and modeling was conducted. The student's objectives were to: (1) Develop a systems understanding of the fundamental behavior of a market; (2) Study and test profit-oriented trading strategies and rules with a systems model that simulates futures trading; and (3) Draw conclusions as to the steps for implementing the results into a personal trading strategy. Various mechanical trading strategies were developed and tested through simulated trading activity in the cotton and pork bellies futures markets. This paper describes the design of the overall experiment and the analysis of several profitable trading strategies.

INTRODUCTION

The Development Needs of the Student

Designing a sequence of systems analysis topics which would meet the development needs and provide a positive learning experience for non-technical graduate students offered an interesting challenge at the Graduate School of Business Administration, University of Virginia. Throughout the two-year Masters of Business Administration Program an analytical problem-solving approach is stressed. An analytical approach including statistics and selected topics in Management Science is used in the study of business management problems in finance, accounting, operations, and marketing. In particular, the student is exposed to various systems simulations, and through the case method he studies--from a generalist's point of view--the practical aspects of successful employment and implementation of systems analysis and modeling.

The student emerging from the MBA program is able to recognize business problems which can be handled by simulation methodologies, and is able to interpret simulation results and utilize those results in decision making. Many students, however, wish to strengthen their generalist's knowledge of systems analysis and its applicability to business management operations and problems. It was this wish that motivated the design of a sequence of topics which would emphasize the role of the manager and the way he affects: (1) Identification of the appropriate problems and viewpoint; (2) Formulation and analysis of the corresponding systems analyses and modeling; (3) Design and implementation of an operational system; and (4) The use of systems outputs as an aid to the decision process. This sequence, covering a time period of one-half of a semester, has now been used for several years in a second year elective at the Graduate School of Business Administration--Management Operations Research. Upon completion of this course, the students should be able to:

- -- Formulate business problems for simulation analysis;
- -- Evaluate models built by others with regards to model validity and utility relative to the problem being studied;
- -- Utilize simulation outputs as one key input into the making of a managerial decision;
- -- Formulate their own set of guidelines for successful implementation of these studies;
- -- Suggest simulation methodologies and experimentation procedures to be used in a systems simulation study.

Pursuant to meeting these objectives, the following types of materials and methodologies were used in the course:

- -- Readings of systems analysis and simulation concepts;
- -- Studies of cases involving managerial problem situations and suggesting a systems model formulation;

-- Studies of cases involving the appraisal of systems models and implementation efforts;
-- The review of periodical articles discussing the state of the art of simulation applications in business;
-- Guest Speakers serving as representatives from the business community who build and use simulation models;
-- Projects and exercises using systems models.

The Futures Trading Opportunity

Regardless of the readings and methodologies employed, the rate of learning can be amplified when conditions exist that will provide a motivating environment for the student. The commodities futures market and its lure of fascinating profits offers such an instrument for conducting a positive learning experience. Building upon the high leverage available when speculating in the futures market, a person of small means can position himself on a mountain of profits, or conversely, lose himself in a pit of losses. Success stories, plentiful in the recent newspapers, tell of the speculators who have obtained 300% return on their invested capital in just a few weeks. Other stories spell out the details of the optimistic speculators who lose their invested capital plus thousands more in just a matter of days.

With this highly motivating environment in mind, a commodities trading exercise was designed with the following objective in mind: Upon completion of the sequence, the student should have the ability and demonstrated competence to:

1. Develop an hypothesis as to the causal factors underlying a systems problem situation. This hypothesis includes specifying both the nature of a problem situation and the fundamental structures thought to be creating the problem and the accompanying time history behavior.

2. Evaluate the validity of a systems model which has been designed to assist the user in an analysis.

3. Manipulate, through model experimentation, sets of decision strategies and rules for the purpose of analyzing and critiquing a simulation approach to solving a specific problem situation.

The commodities trading exercise and its concomitant objectives was placed early in the course in the hope that the usefulness of computer simulation in decision-making would be vividly implanted in the student's mind. It would be an exercise that would instill a creative desire to learn and apply the various systems topics to be studied throughout the remainder of the course. The following sections of this paper describe (1) the systems simulation learning experience which has been conducted in the cotton futures market, and (2) the recent research activities which have been completed by the authors pursuant to the development of futures trading strategies and rules designed to assist the serious trader.

COMMODITY TRADING EXERCISE

Phase I

The commodity trading exercise experience as mentioned above is scheduled early in the Management Operations Research course. The students have the ability to utilize a time-sharing computer system with the BASIC computer language. The exercise starts with several classes devoted to the study of the cotton market. Various articles covering the essential background information on production, consumption, pricing, inventory, governmental, and import and export activities are provided. The students are expected to develop an understanding of some particular aspect of the market time series price behavior by examining the various underlying situations of the market which might be creating the selected price behavior of interest. The approach to be used--that of Industrial Dynamics--calls for the student to (1) select an aspect of the market to study--say the seasonal price movement, and (2) isolate the decision points and related information flows in production, consumption, storage, and governmental sectors, and (3) study how management decisions are being made and how those decisions could be creating the market price behavior of interest. Typically called a fundamentalist's approach, this process has the analyst looking for the underlying structures and relating the actions in these structures to changes in the major market variables. The end product of this exercise is a set of causal relationships which the student believes to be creating his problem situation.

Classroom discussions highlight and reinforce the student's understanding of the cottom market. Computer modeling is not done because of the complexity of the task; however, the students are assigned readings--which they must appraise and critique--on completed systems studies of commodity market behavior.

Phase II

Building upon their knowledge of the cotton market, the students are next asked to examine a technical analysis approach to the study of market price behavior. Given the orientation of a profit-seeking adventure, the students are provided an opportunity to study the decision-making activities of professional commodity futures speculators. The speculator's role in this phase is designed to be similar to that of bringing a manager into the classroom to discuss his job. In class, the speculator discusses his opinions on futures trading, trading strategies, and his decision-making process. In short, he provides a source of expertise for the class, and he serves

as a systems model for this phase of the exercise. The students learn the essential mechanics of trading in the cotton market and gain some insights into the behavior of the decision maker in the cotton futures market.

Phase III

During the next several classes, the students are provided with an opportunity to use a computer-based systems model which simulates futures trading in the cotton market. The model, developed by the authors, simulates the buying and selling of cotton futures contracts based on user-specified decision strategies and technical rules. Several contract years of price data can be used to test the profitability of the strategies and technical rules which have been incorporated into the model. Each student is expected to demonstrate competence in using the model from a researcher's point-of-view, such that he can evaluate its validity and utility as a decision-assisting mechanism in cotton futures trading. A description of the model and the simulated trading exercise follows.

The Trading Model and Trading Exercise

Success or failure in speculative activity can be measured by the profits or losses earned and the accompanying return on personal funds invested in the market. In developing the model, it was theorized that investors' attitudes toward risk taking would differ depending upon whether they were using their own money as a source of investment funds or profits derived from successful transactions. The model therefore counted only those funds which the investors must supply from their personal assets as the investment base. As the trading year progressed, profits decreased the investment base while losses increased the base. The profit (loss) portion of the return calculation was the profits (if any) earned from a given futures contract. It should be noted that the return figures noted in later portions of this paper were not annualized so that the actual annual return is somewhat higher, assuming of course that the trader continues to invest in following contract years.

The simulation model, while containing numerous trading strategies and rules which could be tested, employed a basic core trading logic which was not subject to student manipulation. This "core" logic controlled the process of setting the purchase price and liquidating price once a signal had been given for the model to take some action. The purchase and subsequent liquidation of a long position will be used to explain this process. Establishing and liquidating a short position were handled in a similar fashion.

Establishing A Long Position: The model was based upon the theory that the prices forecasted for the next trading day will be equal to the current average price as expressed by some form of a moving average (either a straight moving average or an exponentially smoothed moving average) plus some degree of deviation from the average. The logic underlying this theory is that when the daily price breaks away from the average (with some degree of deviation) speculators in the market have unusually strong opinions about the value of the contract and price changes can be expected based on those opinions. As Exhibits I and II illustrate for the establishment of a long position, once the daily high price exceeds the moving average plus the breakout zone (the deviation), the computer treats this as a signal that the prices are going to continue to rise. The purchase price may either be (1) the "breakout bid price" specified by the student (Case A in Exhibit II) or (2) the average price of the day if the daily price range exceeds the breakout bid price (Case B in Exhibit II). Obviously, if the daily prices do not exceed the breakout price, no position is taken (Case C in Exhibit II).

Liquidating A Long Position: The key decision in trading centers on the timing of the liquidation of a profitable or unprofitable contract position. Analysis of trading decisions focused on the development of a decision-making strategy which would allow profitable positions to be held and unprofitable positions to be recognized and liquidated promptly. Most traders have trouble with the liquidating decision for two reasons: (1) When profits are first realized in a position, there is a strong tendency to take small profits out of the market, significantly before the upward movement in prices has lost its momentum, or (2) When losses are being accumulated in a position, the trader hopes that the market will turn up and confirm his beliefs of future higher prices; therefore, he tends to hold an unprofitable position for a longer period than is justified. To overcome these two tendencies, the model was designed to allow for the setting of profit and loss targets. The profit target was set "x" dollars or trading points above the purchase price and the loss target (stop loss) was set at "y" dollars or trading points below the purchase price.

In order to maximize the period of time profitable contracts are maintained while minimizing the risk of significant losses, the model checked each contract position each trading day to determine if either target had been reached. If the targets were reached, the position was liquidated and its degree of profitability was calculated. If the daily price had exceeded the profit target previously established by the user, that high price then became a "dummy" or new purchase price and the profit target was then added to it with a corresponding new stop loss also established. In effect, this revision of profit and loss targets established a trading interval around the purchase price so that contracts could be held for as long as the prices indicated that the present trend would continue. As in the purchase routine, a contract would be sold at the stop loss price if that stop loss price fell within the daily trading range; otherwise, the contract would be sold at the average price of the day.

The trading exercise builds upon the students' understanding of cotton market fundamentals and insights into the decision-making activities of

the professional speculator. Given the goal of developing a profitable trading strategy, the students were asked to perform simulation experiments on the trading alternatives available in the model. Model experimentation was conducted in an interactive mode pursuant to the specification of:

1. Price forecasting methodology.
   The type of forecasting to be used:
   - moving average
   - exponential smoothing

   The associated parameters to be used:
   - number of days
   - exponential smoothing constant

2. Model Parameter.
   The degree of deviation (i.e., the value of the breakout zone) to be used above the price forecast:
   - when the daily price moves outside the breakout zone, a position is established

3. Model Parameter.
   The profit factor to be added to the contract price:
   - this profit objective is used to signal the liquidation of a position. The model provided for the option of (1) having the project target move up in a long position as the prices moved up and vice versa for a short position, or (2) having the profit target remain unaffected by the price movement

4. Model Parameter:
   The stop loss factor to be added to the contract purchase price:
   - this loss objective is used to signal the liquidation of a position.

Runs were made on three contract years of cotton data. These data have different time series characteristics of movement and the students were challenged to determine the applicability of a trading strategy to each of the three contract years.

One of the most important aspects of this exercise is the analyses of attainment of the profit goal. As expected, widely varying profit and loss results are attainable as the model is tested with the several trading strategies for each specification listed above.

After the simulation experiments were completed, the second aspect of the exercise called for the students to suggest and hopefully test trading strategies which have not been programmed into the model. For example, the model structure might be changed to reflect a different price forecasting mechanism such as a time series regression model.

Phase IV

In the final phase, the students were expected to prepare group reports which summarized their research using the trading model. In particular, the following topics were addressed:

1. Research Procedure;
2. Results of the Test Runs;
3. Conclusion as to the model's Trading Strategy and Rules;
4. Alternative Trading Strategies;
5. Plans for Implementing their Results into a Personal Trading Strategy.

Some Results of the Cotton Trading Exercise

Even though nine classroom hours and twenty-four class preparation hours were planned for the exercise, the students felt that more course time should be set aside for the exercise. The exercise accomplished the goal of providing a stimulating and motivating foundation for the remainder of the course and the instructor and students saw the specific learning objectives achieved.

Some simulated trading results for three cotton contracts are shown in Exhibit III. These model runs represent only a very small number of the total runs performed; however, the results from two strategies listed in Exhibit III are typical.

In class discussions after this exercise, a number of alternate strategies were discussed, particularly ones which dealt with the purchase signals being given by the model. The students felt that the use of a constant breakout zone was unrealistic in that it did not adjust to the behavioral pattern of a given market. It was evident from the runs that profits could be earned as shown in the case of restricting the number of contracts which could be held at any one time. The students concluded that a smoothing constant of 0.4 worked best with the exponential smoothing model and the other conditions specified.

RECENT RESEARCH ON TRADING STRATEGIES

Because of the interest shown by the students and the lure of profits, the authors undertook a study which began at the point at which the students ended. The most important aspect of this analysis was not the selection of rules which would give the best results. These "numbers" can be determined by the computer through the use of a simple search routine. What is important is the selection (out of many alternatives) of methods whereby a computer simulation will determine the best strategies—strategies which will enable the trader to apply them to many different types of markets. Due to the large number of alternative strategies, several alternatives were selected based upon an understanding of the fundamental nature of the markets which were to be simulated.

- Hold only one contract at a time;
- Alternate the purchase of long and short contracts;
- Wait a specified number of days between purchases (even though a signal has been given);
- Invest only a specified quantity of money in the market;
- Use an exponential smoothing model to forecast the next day's prices;
- Use variable (i.e., a function of current activity) breakout zone forecasted prices;
- Use either a fixed or variable stop-loss factor.

It can be readily seen that some of these strategies reflect one's personal attitudes toward risk. This is a necessary and vital part of any systems analysis process.

Recent Research Results - Cotton Contracts

At the outset, it was decided to treat the problem as one of forecasting. The theory was that tomorrow's price would be the same as the present average price plus or minus some degree of deviation or confidence interval (based on the variance of the daily price levels). As can be seen from the results of Strategy I in Exhibit IV, the best combination of rules was to trade right on the moving average (here again an exponentially smoothed average was chosen for the sake of simplicity) while delaying the sale of contracts until a clear losing trend had been established.

It can be seen in Exhibit IV that as experiments were made with different rule combinations, significant improvements began to occur, especially when a constant stop loss--Strategy II--was used together with a two-day purchase delay. This particular strategy probably prevented the model from reacting to as many false signals as given by the strategy of buying every time a signal was given. It should also be pointed out that this strategy allows the "small" investor to enter the market with a limited supply of funds. The professional investor would only have to purchase multiple contracts to make this strategy worth his time and energy.

Other trading strategy/rule combinations were tested, but with less success. One interesting series of strategies is one in which restrictions were placed upon the number of contracts that could be held at any one time and/or alternated buying long and short contracts (See Exhibit V). Although the return figures are impressive, it should be pointed out that they are based upon a very limited number of trades and may be a reflection of the data and not the validity of the strategy.

After completing our investigations, the most successful strategy/rule combinations were tested one final time against three previously untested contract years, one cotton, and two pork bellies (See Exhibit VI). The results were quite interesting. The cotton contract year failed to give any profitable results while the pork belly contract years supported the selection of a variable breakout, constant stop loss, and two-day purchase delay strategy. Upon further investigation, it was found that the cotton contract year never varied more than three points and exhibited a random price movement throughout. This is one instance in which the basic theory of the whole project breaks down. No model can predict random fluctuations. The professional trader would probably have abandoned the market at least by the half-way point so that actual losses would probably be somewhat less than those indicated.

In conclusion then, it appeared that the strategy/rule combinations listed above seem to offer some promise, but it should also be pointed out that it would be foolish indeed to immediately conclude that anyone using these rules can become a professional trader. The model needed to be refined and tested on other data.

Recent Research Results - Pork Bellies Contracts

Although the results of the cotton markets simulation showed promise, several shortcomings were uncovered. First, the data that were used contained only the high and low daily prices. It is not reasonable to assume that contracts can be bought and sold anywhere within this range. Therefore, six contract years of pork bellies data which contained the opening price as well as the high and low daily prices were collected. The model was then changed so that if the opening price was above the breakout price, a long contract would be bought at the opening price. Similar changes were made for selling long contracts and for short contracts. Contrary to prior assumptions, four of the six contract years exhibited higher returns (See Exhibit VII). This addition, while more accurate, did not appear to be as conservative as our initial model assumptions.

The second line of investigation was to attempt to construct a model which would eliminate the negative returns of the February, 1973 pork bellies contract year. Unlike the 1971 cotton contract year, February, 1973 pork bellies appeared to fluctuate enough to allow for profitable trading. The rules which had been developed prior to this were rules designed to fit a number of markets, but obviously not all. Each contract year exhibits a certain daily price fluctuation (high and low), a certain day-to-day price movement, and a certain cyclical pattern. When the characteristics of a market begin to fall outside the range of those markets used to develop the strategies and rules, the model immediately loses all validity.

The assumption that the characteristics of a contract year could be ascertained by the time the market had progressed for a period of time was made. For the purpose of the analysis, a sixty-day period at the beginning of the market was chosen as the test period. (The first month of data in the contract year had already been completely eliminated from consideration due to the fact that trading during this period is so light that slight changes in supply and demand would cause larger than normal changes in price data.) The same trading strategy was used (variable

breakout zone, fixed stop-loss, and a two-day purchase delay). This strategy had proven to be successful. The model was then changed to vary each trading rule in turn (alpha value for the exponential average, number of deviations for the breakout zone, and stop-loss value) and to pick that combination which resulted in the highest return on investment. It was found that in every case but one, the return figures were higher (See Exhibit VIII). Sadly though losses were still suffered in February, 1973, although the losses were approximately one-half those incurred in the original model.

CONCLUSIONS

The futures trading exercise was developed for the purpose of involving the student in such a highly stimulating environment that the learning process would be amplified. The study of management decision-making is often conducted in the cold, abstract environment of mathematical approaches, decision models, and computer-based systems. In this exercise, the student was involved as the decision maker in the futures market. He was designing his own personal trading strategy and rules--whether they be a high risk-potentially-high reward and loss, or a low risk-potentially-low reward and loss strategy. He was developing the approach by which he will implement his results and/or conduct additional research.

The students were asked to analyze the fundamental nature of the markets being simulated; to develop a set of profitable trading strategies which predicted the price movement of a particular contract year and which fulfilled the criterion that they be simple enough for an actual trader to use with a minimum of effort; to apply these strategies to the simulation model to determine the best set of trading rules (values); to analyze the results to determine the validity of their strategies; and finally, to suggest (and hopefully test) alternative strategies which would improve the predictability of price movement and hence, return on investment.

Together, the futures market environment and the computer-based trading and decision model, provide a positive learning experience and a foundation for the subsequent course topics in systems analysis and modeling.

The research conducted by the authors demonstrated that profitable futures trading strategies and rules can be analyzed through systems analysis and computer simulation. The results were derived through the employment of mechanical or technical trading techniques. The techniques themselves were formulated to detect sustained or major price movements, to position a trader in the market at the right time, to protect his investment against significant losses, and to take significant profits from the market.

Although the trading strategies and methods of determining the proper rules appear to offer some promise of success in the actual market place, their major strength and weakness lie in their inflexibility. Amateur traders can supplement their lack of knowledge of the fundamental approach to market analysis by following the model "to the letter." Professional traders can probably strengthen their fundamental analysis by using the model as a vehicle to determine bid and stop loss prices. This is particularly true for the selling routine. Since a large number of liquidated contracts actually develop into turnaround situations, the professional trader can adjust the stop losses to reflect his thoughts as to the predominant trend in the immediate future. The model and this approach, if accepted by the professional trader as being valid, should improve his results substantially.

EXHIBIT I

Purchase Signal Theory

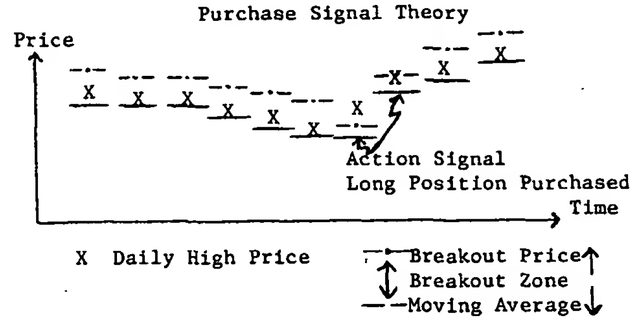
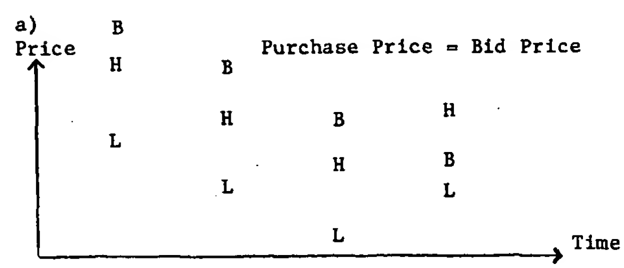


EXHIBIT II

Contract Purchase Prices

H = Daily High; L = Daily Low; B = Bid Price



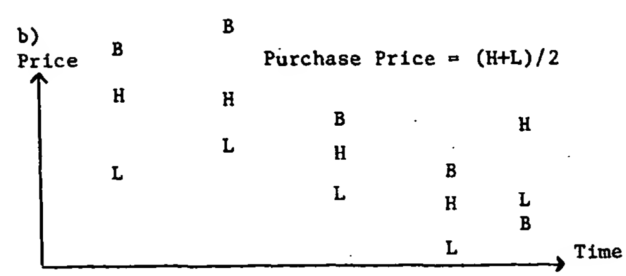


EXHIBIT II (Continued)
Contract Purchase Prices

H = Daily High; L = Daily Low; B = Bid Price

c)

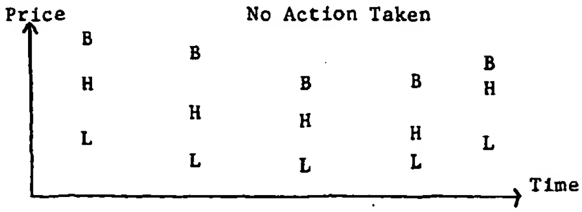


EXHIBIT III

Some Results of the Cotton Trading Exercise

STRATEGY I: Set a fixed profit target, do not adjust the target and liquidate at the fixed profit target or at the stop loss target.

Hold only one position at a time.

Rules: Exponentially Smoothed Average with
α = smoothing constant
Breakout zone = 50 points above the price forecast
Profit target increment =
100 points above purchase price
Stop Loss Factor =
70 points below the purchase price

Run with varying α:

a) Cotton

May 1968	Profit	Return
α = .7	$ -207	-10%
α = .6	-199	-10%
α = .5	-155	- 8%
α = .4	579	36%
α = .3	549	34%
α = .2	-344	-17%

b) Cotton

May 1969	Profit	Return
α = .7	$ -140	-10%
α = .5	- 86	- 6%
α = .4	575	48%
α = .3	360	30%

c) Cotton

May 1970	Profit	Return
α = .7	$ 455	38%
α = .4	910	76%
α = .3	910	76%

STRATEGY II: Set a profit target and establish "dummy" purchase prices by setting new profit targets and stop loss points once original target has been achieved. Contracts now will only be liquidated at the stop loss points.

Hold any number of contracts.

EXHIBIT III (Continued)
Some Results of the Cotton Trading Exercise

Rules: Exponentially Smoothed Average with α = .4
Breakout zone = 50 points above the price forecast
Stop Loss Factor =
70 points below purchase or "dummy" purchase price
Profit target: variable

a) May 1968 - Cotton

Profit target increment = 0*:

Profit	Return
$ -4,514	-83%

Profit target increment = 100 points:

Profit	Return
$ -2,317	-10%

b) May 1969 - Cotton

Profit target increment = 0*:

Profit	Return
$ -3,647	-73%

Profit target increment = 100 points:

Profit	Return
$-16,110	-59%

c) May 1970 - Cotton

Profit target increment = 0*:

Profit	Return
$ 1,168	97%

Profit target increment = 100 points:

Profit	Return
$-16,272	-33%

* A zero profit target increment changed the model logic so that, if the high price today is greater than yesterday's price, today's price would become the new "dummy" purchase price. All other routines remained the same.

EXHIBIT IV

Cotton Contract Simulation

STRATEGY I: Exponential Smoothed Average
Variable Breakout Zone
Variable Stop Loss Factor

Rules: No Purchase Delay
$\alpha = .4$

Break-out (a)	Stop Loss (b)		May Cotton Contract Year 1968	1969	1970
0	2	profits	$27,011	$27,829	$11,923
		returns	40%	33%	25%
-2	2	profits	$22,175	$31,319	$14,853
		returns	30%	34%	28%
0	1	profits	$37,447	$ 4,847	$10,451
		returns	86%	15%	31%

[a] number of standard deviations from the moving average of the daily high price

[b] number of standard deviations below the moving average of the daily low prices (for a long contract)

STRATEGY II: Change from Variable to Constant Stop Loss Factor

a) Rules: No Purchase Delay
Stop Loss Factor =
70 points from the purchase price
Variable Breakout = 0
(purchase on the price forecast)

	May 1968	May 1969	May 1970
Profits	$13,996	$19,959	$36,284
Returns	77%	42%	38%

b) Rules: Purchase Delay = 2 days

	May 1968	May 1969	May 1970
Profits	$ 7,372	$ 7,300	$13,649
Returns	174%	45%	40%

EXHIBIT V

Alternate Cotton Contract Strategies

STRATEGY I: Exponentially Smoothed Average
Hold only one position at a time
Alternate long and short positions
Variable Breakout Zone
Constant Stop Loss Factor

Rules: $\alpha = .4$
No Purchase Delay
Variable Breakout = 0 deviations
Stop Loss Factor = 70 points from the purchase price

	May 1968	May 1969	May 1970
Profits	$ 578	$1,318	$2,015
Returns	24%	110%	168%

STRATEGY II: No Restriction on Alternating Positions

	May 1968	May 1969	May 1970
Profits	$1,723	$1,824	$1,950
Returns	67%	140%	163%

EXHIBIT VI

Strategy/Rule Testing

(May and July 1972 Pork Bellies)
(May 1971 Cotton)

STRATEGY I: Exponentially Smoothed Average
Variable Breakout Zone
Constant Stop Loss Factor

Rules: $\alpha = .4$
Variable Breakout = 0 deviations
Stop Loss Factor = 70 points from the purchase price
Purchase Delay = 2 days

	May 1972 Pork Belly	July 1972 Pork Belly	May 1971 Cotton
Profit	$8,161	$5,820	$-6,230
Returns	139%	145%	-32%

EXHIBIT VII

Investigation with Pork Bellies Contracts

Overall Strategy and Rules: Exponentially Smoothed Average
$\alpha = .4$
Variable Breakout = 0 (trade on the price forecasted)
Fixed Stop Loss Factor = 70 points
Purchase Delay = 2 days

Case (a): Trade on only high and low prices

	August 1971	August 1972	August 1973
Profits	$6,353	$3,286	$7,417
Returns	114%	60%	95%

	February 1971	February 1972	February 1973
Profits	$7,728	$11,072	$ -93
Returns	80%	116%	-1%

Case (b): Trade on open, high and low prices

	August 1971	August 1972	August 1973
Profits	$7,763	$4,817	$3,967
Returns	129%	85%	66%

	February 1971	February 1972	February 1973
Profits	$8,091	$13,009	$-3,562
Returns	83%	206%	-41%

EXHIBIT VIII

Results of Computer Predictions

Contracts	Trading Results Based on 60-day Simulation to obtain Trading Rules	Previous Results Obtained Based on Rules in Exhibit VII, Case (b)
1) August 1971 Pork Bellies		
Rules: .4, 2, 70, 50[a]		
Profits	$2,876	$7,763
Return	239%	129%
2) August 1972 Pork Bellies		
Rules: .4, 2, 30, 50		
Profits	$2,187	$4,817
Returns	182%	85%
3) August 1973 Pork Bellies		
Rules: .4, 2, -70, 50		
Profits	$2,107	$3,967
Returns	72%	66%
4) February 1971 Pork Bellies		
Rules: .4, 2, 50, 50		
Profits	$3,483	$8,091
Returns	96%	83%
5) February 1972 Pork Bellies		
Rules: .4, 2, 0, 60		
Profits	$2,949	$13,099
Returns	133%	-41%
6) February 1973 Pork Bellies		
Rules: .6, 2, 40, 40		
Profits	$-1,767	$-3,562
Returns	-68%	-41%

[a] Each set of rules for alpha, breakout zone, profit factor, and stop loss factor was determined based on 60 days simulation. For example, the following values were determined for August, 1971 Pork Bellies:

$.4 = \alpha$ — 2 = Breakout Zone (deviations)
70 points = Profit Factor — 50 points = Stop Loss Factor

ROBERT D. LANDEL, Associate Professor of Business Administration, Graduate School of Business Administration, University of Virginia; Ph.D. in Industrial & Systems Engineering, Georgia Institute of Technology; Formerly Industrial Engineer and Raw Materials Buyer for Westinghouse Electric Corporation.

CHARLES C. CHEWNING, JR., Assistant to the Managing Director, C. H. Bailey Group, Cardiff, Wales; MBA, 1973, University of Virginia; Formerly Manufacturing Supervisor for Westinghouse Electric Corporation.